Using Data Manager® 2000 to compete in the wholesale power market

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American Electric Power (AEP) is a global energy company and one of the largest investor-owned utilities in the United States. Our facility at St. Albans, West Virginia, is a coal-fired generating plant, which produces 2900 MW of power. We use a Bently Nevada 3300 Turbine Supervisory Instrumentation System and proximity probes to monitor the three turbines in our plant. We also recently installed a Data Manager® 2000 System on our 1300 MW, cross-compound, Asea Brown Boveri (ABB) turbine generator as part of a system demonstration.

The locations of the eight bearings on each turbine-generator shaft, HP and Reheat, are the same, but are quite different from the standard bearing arrangement used by many American turbine manufacturers (Figure 1). The HP turbine rotor has the standard two bearings, but on the LP A rotor there are no bearings within its coupling span. On the LP B rotor, there is only one bearing on the governor end. There are bearings on each end of the generator and the exciter.

The Data Manager 2000 (DM2000) System automatically collects and processes vibration and process data during both steady state and transient (startup and coastdown) machine operation. Under steady state conditions, the DM2000 System samples all configured points once every four seconds and retains the minimum, maximum, and average value for each point over a ten-minute interval. The DM2000 can be configured to automatically capture data by intervals of delta rpm, delta time, or both, during startup and shutdown.

Vibration triggers overspeed bolt, trips turbine

In April 1998, we completed a long outage, during which the two LP turbines on the HP shaftline were inspected and refurbished. After the outage, we operated the turbines successfully until the unit was forced from service on April 26, due to high vibration on the HP turbine shaftline. Initially, vibration levels only increased on the T-3 and T-4 bearings, but vibration amplitudes on the other bearings, including the T-1 bearing, soon increased as well. At the time, unit operators suspected that the vibration may have been caused by turbine backpressure, but attempts to lower the backpressure to reduce the vibration were not successful. Vibration levels continued to increase until the HP turbine 110% overspeed bolt operated and tripped the turbine and the unit. As we experienced previously, the overspeed bolt operated, due to the high vibration at the T-1 bearing and front end of the HP rotor. Following the trip, a root cause analysis was initiated but couldn't be accomplished, as the turbine vibration data acquisition system was not in service at the time of the trip. Therefore, further analysis of the vibration

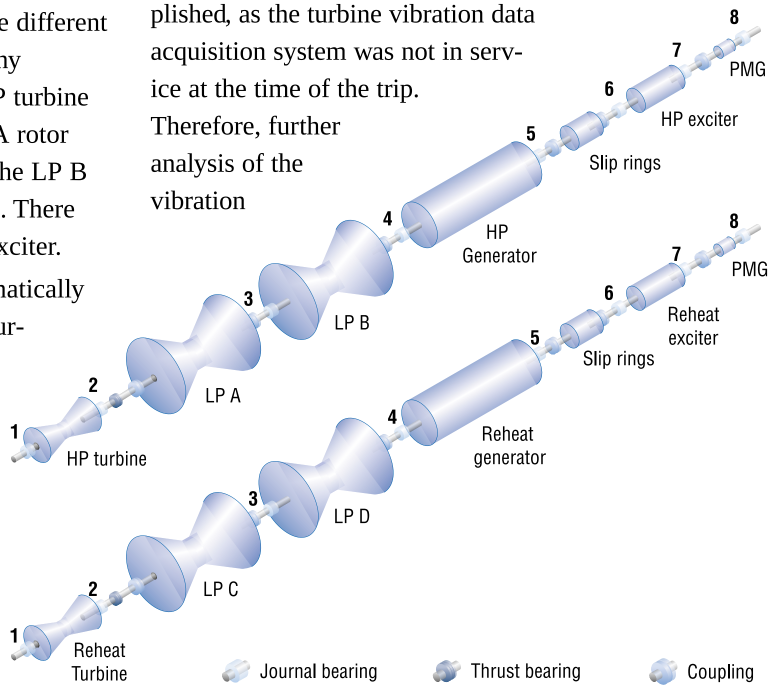

Figure 1. Block diagram of ABB 1300 MW, cross-compound turbine generator.

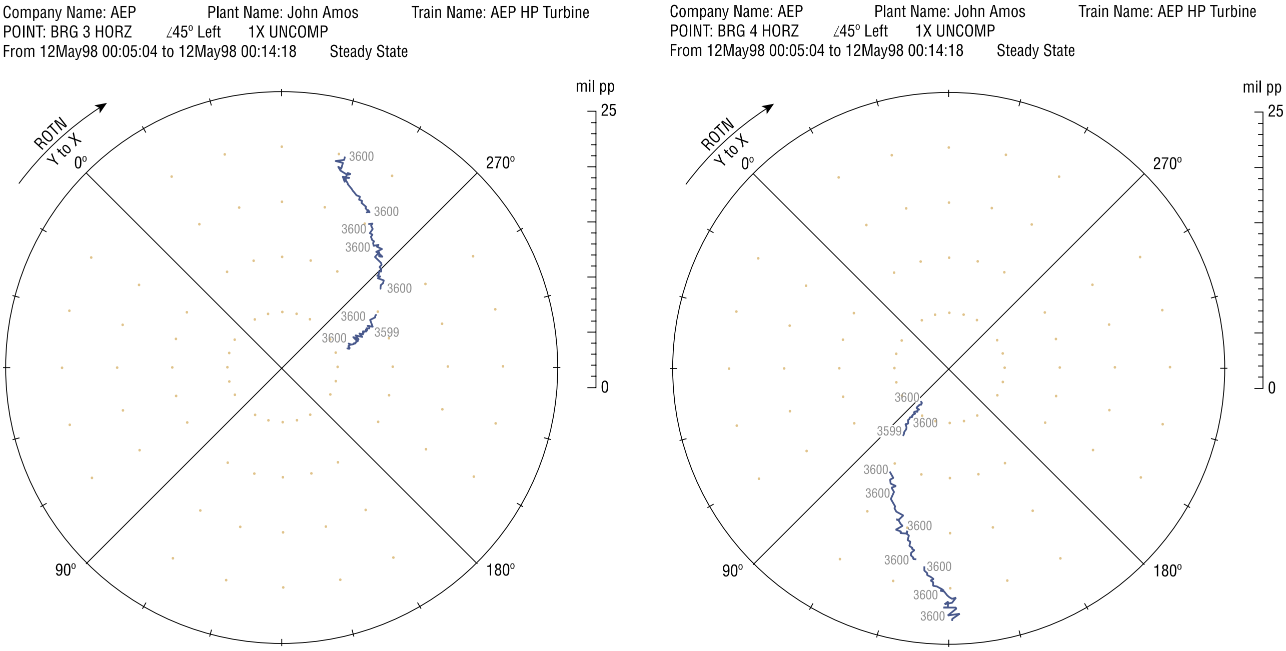

Figure 2. Steady state vibration response at bearings 3 and 4 due to thermally-induced rub.

characteristics was not possible. The unit's Sequence of Events Report (SER) printout did not indicate any pre-trip events that may have contributed to the vibration excursion. Also, no abnormal data, which could be related to the trip, had been reported in the control room.

Second machine trip

The unit was returned to service and operated successfully until May 12, when System Dispatch asked that the unit load be reduced to minimum. Similar to the events of the previous trip, the vibration levels first increased on the T-3 and T-4 bearings. The other bearings quickly followed, including the T-1 bearing, until the overspeed bolt again tripped the turbine. Once again, a root cause analysis was initiated. The premise was that unit load changes, with their associated thermal influences, might be creating a rotating-to-stationary-component rub. In particular, since the LP turbines had recently been overhauled, we suspected that the tight seal clearances were the most likely source of the rub. Therefore, we began to evaluate the vibration data for evidence of a rub. Since the DM2000 captured vibration amplitude, phase angle, and frequency data before and after the unit trip, we had access to information which could help identify a thermal rub. Characteristically, during a thermal rub, the phase angle and the vibration amplitude both change gradually over time, and the vibration frequency is predominately 1X (synchronous). A quick review of the polar plots from the Data Manager 2000 System (Figure 2) showed that the vibration amplitude and phase lag increased as the rub-induced bow changed the balance condition of the LP rotor. Therefore, we concluded that an LP turbine rub had occurred.

In addition, the timebase and orbit plots for bearings 3 and 4 (Figure 3) clearly showed the restraint and noncircular centerline motion of the shaft. This is very consistent with a rub malfunction. The orbit at bearing 3 was also "reverse" precession (against the direction of rotation) orbit. This is caused by tangential forces acting on the rotor, due to friction from the rub event.

Thermal analysis

After diagnosing the LP turbine rub, we began to look for possible thermal influences that may have initiated the rub. For an LP turbine rub, the turbine gland seal system is often found to be the culprit. Upon inspection, it was found that the steam seal system's attemperation (desuperheater) valve was malfunctioning, due to a problem with an air solenoid valve that supplies its controlling signal. The valve problem, in conjunction with the tight LP seal clearances, resulted in a gland seal rub with the LP rotor. After the valve was repaired and temperature control was returned to normal, no further vibration excursions have occurred.

Conclusions

After reviewing the probable results if the rub had contin-

ued, we realized that the turbine would not have suffered any significant damage. It also would not have been necessary to open any turbine section. However, identifying and correcting the attemperation valve problem certainly avoided additional trips. Without the data from the DM2000 System, we wouldn't have been able to identify the problem so quickly and accurately. **Thus, the real story here is the savings the DM2000 System generated.** The application of diagnostic and predictive maintenance techniques at our plants is instrumental in avoiding unplanned shutdowns, which is crucial to meeting our customers' power requirement and optimizing our profitability in the wholesale electric market.

An unplanned unit shutdown can significantly affect our activities in the wholesale power market, including reversing our position from a net seller to a net buyer. Last summer, the Midwest experienced several hot, humid months, including a late June heat wave, which precipitated unprecedented price levels in the wholesale electric market in the Midwest. Prices in the Day-Ahead market, which involves daily prescheduled energy blocks for the sixteen on-peak hours of the following day, were frequently in the $30-$50 per MWh range, with a number of peak days exceeding $100 and even $1000 per MWh. Similarly, prices in the hourly marker, which involves the trading of hourly energy blocks, were often in the $50-$100 MWh range.

With these market conditions, the unexpected loss of a large unit can have substantial financial impact in only one afternoon. As an example, based upon the available spinning reserve at the time of the trip, the loss of a 1300 MW unit may lead to the need to purchase 700 MW of replacement power in the hourly market for up to 4 peak hours. **Assuming an energy cost of $100/MWh, the resulting replacement energy cost is 700 MW x $100/MWh x 4 hours = $280,000 for a single trip, and potentially a great deal more!**

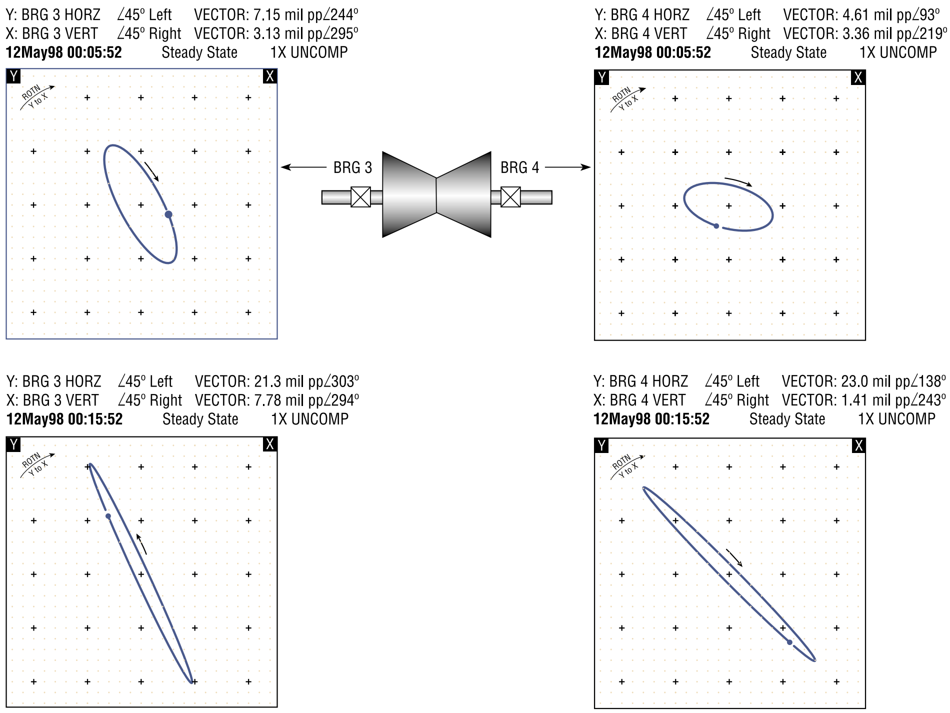

Figure 3a. 1X shaft orbits at bearings 3 and 4. Top plots show response shortly after startup. Bottom plots show effects of thermally-induced rub.

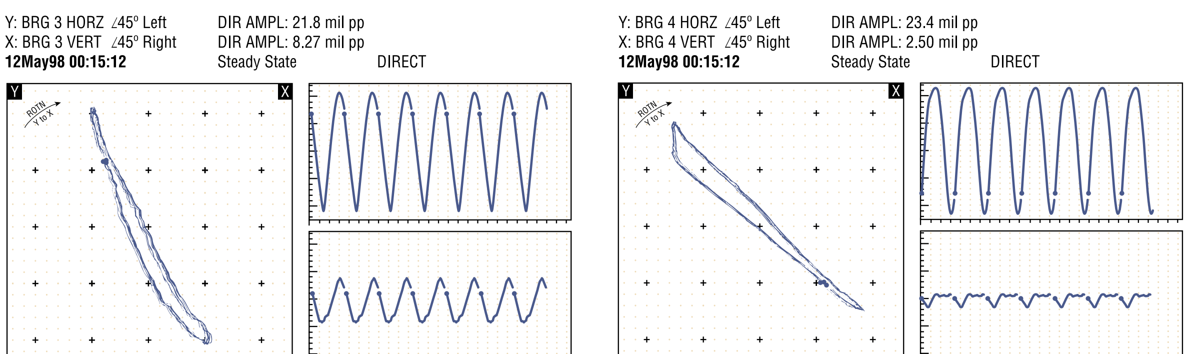

Figure 3b. Direct orbit and timebase plots of response due to thermally-induced rub at bearings 3 and 4. Notice truncated response of waveform in positive X probe direction at bearing 4 indicating duration of contact. Corresponding flat area of orbit shows orientation of rub location.